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Final dissertation

Effects of numerical magnitude on action judgements in school-aged children

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ABSTRACT

This thesis explores the relationship between numerical cognition and motor processes in children, with a focus on the interaction between numerical magnitude and action-related judgments. The study builds on the findings of Badets et al. (2007) that irrelevant numbers can influence graspability judgments in adults. This study wants to know whether a comparable effect occurs in school-aged children. A total of 51 children between the ages of 6 and 10 participated in a computerized task in which they had to judge the graspability of rods of different lengths presented after numerical primes (small: 2–3; large: 7–8). Standardized tests of numerical competence (e.g., AC-MT), fine motor skills (e.g., ABC battery), and finger gnosis were also administered.

The results determine if numerical primes systematically influence children's graspability judgments and if this effect is affected by developmental factors, such as age, numerical ability, and motor skills. This study contributes to the growing field of embodied numerical cognition by examining how children's understanding of numbers changes over time and how this change depends on the sensorimotor systems.

1. INTRODUCTION

Understanding how humans acquire and process numerical information is a central topic in developmental and cognitive psychology. Numerical cognition is fundamental not only for academic learning, but also for managing everyday activities across the lifespan, supporting skills such as time management, financial decision-making, and health-related reasoning (Butterworth, 1999) (*OECD Skills Outlook 2013*, 2013).

The development of numerical skills during childhood shows to have long-lasting implications for educational achievement and even professional careers later in life (Duncan et al., 2007). For this reason, the mechanisms that support the acquisition of numerical abilities during the first school years are a priority in both research and educational policy. Over the past decades, research has suggested that numerical abilities emerge very early in life, even in infancy, through an innate intuition often referred to as the "number sense" (Izard et al., 2009; Dehaene, 2011; F. ry et al., 2005). This skill allows individuals to perceive, compare, and manipulate quantities without relying on language or symbols, forming the foundation for later symbolic and formal mathematical learning (Geary, 2000; Girelli et al., 2000). Despite the conventional view of numbers as abstract symbols, there is increasing evidence that their mental representation is deeply connected to sensorimotor experience; for instance, children often use their fingers to count, represent quantities, and perform basic calculations, even from early childhood. This finger-based interaction is not only a compensatory strategy, but it probably plays an active role in building the mental architecture of number concepts (Fisher 2008; Noël, 2005). According to the embodied cognition framework, cognitive processes (including numerical reasoning) are dynamically shaped by interactions between the body and the environment (Gallese & Lakoff, 2005). In this view, finger gnosis and fine motor skills are not marginal to the acquisition of mathematical skills, but they can be essential developmental tools, especially in early childhood (Fayol, 1998; Penner-Wilger et al., 2007).

Several empirical studies have confirmed the existence of significant correlations between motor coordination and mathematical performance in children (Cameron et al., 2012; Grissmer et al., 2010) In particular, different studies have shown that early finger gnosis and fine motor abilities are significant predictors of later numeracy, even when controlling for general intelligence or language skills (Barrocas et al., 2020; Suggate et al., 2017).

The present research focuses specifically on children aged 6 to 10 years, an age range characterised by rapid development of both fine motor control and numerical competence. The central question is whether the perception of numerical magnitude can implicitly influence action-related judgments in school-aged children, particularly the perceived possibility of grasping an object with thumb and index finger. This idea builds on previous findings by Badets and colleagues (2007), who showed that numerical primes modulate motor decisions in adults: participants were more likely to judge an object as graspable when it was preceded by a small number, and less likely to do so when it was preceded by a large number. This phenomenon was interpreted as an interaction between numerical size and affordance perception, highlighting the connection between symbolic and motor representations.

1.1 THEORETICAL BACKGROUND

1.1.1 NUMERICAL COGNITION IN CHILDHOOD

Numerical cognition includes a wide range of abilities, from basic quantity discrimination to formal arithmetic reasoning. One of the earliest developing components of numerical cognition is the Approximate Number System (ANS), a non-symbolic representation of magnitude that appears in infancy and lay the foundation for a later symbolic numerical processing (Halberda et al., 2008; Dehaene, 2011). Research has shown that even newborns can detect changes in numerosity, suggesting that humans have an innate number sense (Izard et al., 2009; F. Xu et al., 2005). As children grow, this intuitive system interacts with culturally acquired skills such as counting and number-word mapping (Geary, 2000; Wynn, 1990), creating the bases for formal mathematics. The precision of this internal magnitude representation correlates with later mathematical achievement in childhood and adolescence (Krajewski & Schneider, 2009; Mazzocco et al., 2011). Moreover, children’s ability to estimate, compare and manipulate quantities improves over time and becomes more automatic, as proved in studies on numerical estimation and magnitude comparison (Booth & Siegler, 2006; Girelli et al., 2000). Rather than being a secondary support, motor coordination appears to play a functional role in sharing numerical understanding. For example, young children often rely on their hands to count, visualize quantities, and solve simple arithmetic problems, all strategies that are not only practical, but also conceptually meaningful, showing that there is a deep connection between abstract ideas and bodily experience (Noël, 2005; Penner-Wilger et al., 2007).

1.1.2 MOTOR SKILLS AND FINGER GNOSIS

As suggested by recent studies, motor skills and the use of fingers may play a key role in numerical learning than previously thought. Finger gnosis, the ability to identify and mentally represent each finger, has been linked to better performance in mathematical tasks (Noël, 2005). Using fingers can help children internalize numbers, as the movements and sensations involved create a strong link between the body and number concepts (Penner-Wilger et al., 2007). This connection allows children to “experience” numerical operations (like addition or subtraction) directly through physical actions, making abstract number properties more tangible (Barsalou, 2008).

Further evidence by Fischer and colleagues (2022) shows that preschoolers with better finger agility and speed also perform better in finger-based tasks and symbolic arithmetic. Moreover, Asakawa & Sugimura (2022) found that fine motor control predicts children's ability to count with fingers, supporting their early calculation skills. From a neurological point of view, recent neuroimaging research suggests that the brain regions involved in finger representation, such as the somatosensory cortex and intraparietal sulcus, are also activated during number processing (Berteletti & Booth, 2015; Ranzini et al., 2022), supporting the hypothesis of overlapping neural circuits for fingers and numbers, possibly formed through early finger-based counting experiences.

1.1.3 NUMBER-ACTION INTERACTION IN ADULTS AND EMBODIED PERCEPTION

The concept of affordances was first introduced by Gibson (1979), to describe the possibilities for action that the environment offers to an organism in relation to its body and capabilities. According to this view, perception is intrinsically linked to action: objects are not perceived passively, but rather in terms of what they afford, what they allow or invite the perceiver to do. For example, a cup is seen not just as a cylindrical object, but as something that can be grasped and lifted, making this concept essential to understand perception as action-oriented. Neuroscientific research has supported this view, proving that observing an object automatically activates motor representations associated with interacting with that object (Caggiano et al., 2022; Grèzes & Decety, 2002). These findings have been interpreted as evidence for a perceptual system that codifies not only the visual features of objects, but also their functional properties. This connection between *how we think* and *how we act* is known as the action-perception coupling.

In the context of development, children gradually learn to calibrate their judgments of affordances (reachability, graspability, etc.) based on their own physical abilities and experiences (Franchak, 2019). These affordance judgments are not static but change with context and task demands, and they can be modulated by abstract cues such as numbers. Within this framework, a key study in this area was conducted by Badets et al. (2007), who investigated whether numerical magnitude could influence action-related judgments in adults. In their experimental paradigm, participants were asked to judge whether a series of bars presented on a screen could be grasped with a precise grip (i.e., between the thumb and index finger). Before each judgement, a single digit number was briefly displayed on the screen. Although the number was irrelevant to the task, it had a systematic influence on participants' responses: small numbers (e.g., 2 or 3) increased the likelihood of judging the rod as graspable, while large numbers (e.g., 7 or 8) had the opposite effect. This finding was interpreted as evidence for a strong connection between numerical size and motor representations.

To test the specificity of this effect, the authors conducted control experiments in which participants made a perceptual comparison of rod lengths without any motor judgement. In these cases, numerical priming did not affect performance, suggesting that the effect observed in the graspability task was not due to changes in visual perception, but instead to motor simulation mechanisms activated during action planning. In other words, the numerical primes seemed to bias the internal representation of the motor system rather than changing the perceived size of the rods.

These findings are in line with the theory of embodied numerical cognition, which posits that numerical processing (especially in early developmental stages) is grounded in sensorimotor systems. Badets and colleagues extended this view by showing that such numerical processing persists into adulthood, long after finger counting strategies have been abandoned. Their work provided empirical support for the idea that numbers are mentally represented in ways that overlap with action planning systems, particularly those involving grasping.

Subsequent studies have also confirmed and extended these findings. For example, Andres et al. (2004) showed that numerical magnitude modulated grip aperture during the physical execution of a grip: small numbers facilitated smaller grip apertures, while larger numbers led to wider grips. Neuroimaging studies (Pesenti et al., 2000; Simon et al., 2002) have also shown that both numerical processing and hand actions recruit overlapping areas in the intraparietal sulcus, a region associated with magnitude representation and motor control. Motor behaviours go also beyond grasping: Shukla & Bapi (2021) found that irrelevant numerical magnitude can modulate temporal judgments, and, in fact, participants exposed to larger numbers tended to overestimate time intervals. Since temporal estimation is essential for motor planning and coordination, these results indicate that numerical magnitude may influence time-sensitive aspects of motor behaviour. In addition, Anobile et al. (2024) emphasized that number representations are deeply embedded in action-perception cycles, highlighting how numerical processing is not only connected to manual actions like grasping but also with posture, movement timing, and eye-hand coordination.

1.2 THE PRESENT STUDY: AIMS AND HYPOTHESIS

Despite the growing interest in the relationship between numerical cognition and motor processes, current research is heavily focused on adult populations. It is unclear whether this interaction is present during childhood or whether it is influenced by individual differences in numerical competence or by age-related changes in motor and cognitive control. Given that symbolic number processing becomes more abstract with age and education (C. Xu & LeFevre, 2021), and that children have quite different levels of understanding when it comes to numbers, it is plausible that the strength or presence of the number-action interaction may vary significantly as they grow up. As previously discussed, early numerical skills are closely linked to sensorimotor experience, particularly the use of fingers for counting and problem solving (Noël, 2005; Penner-Wilger et al., 2007), which may lay the foundation for symbolic number processing, and individual differences in finger gnosis and fine motor control have been linked to early numerical competence even before formal school begins. (Fischer et al., 2022). With formal education children tend to gradually replace finger-based counting strategies with more efficient mental calculation methods, suggesting a shift from embodied strategies to internalized numerical representations (Poletti et al., 2022). This raises the possibility that embodied numerical effects, such as the modulation of graspability by number size, may be stronger in early stages or emerging only after certain cognitive barriers have been overcome.

Another open question concerns the role of numerical competence in modulating action-related responses. In adults, the effect observed by Badets and colleagues occurs without explicit mathematical processing and appears to be automatic. In children, however, the ability to mentally represent numerical magnitude and to inhibit irrelevant information varies across developmental stages (Von Aster & Shalev, 2007), making difficult to understand how numerical magnitude can bias motor judgments. Furthermore, recent theoretical work has proposed a new ontology of numerical cognition that integrates evolutionary approaches, body-based learning and computer models, highlighting that numerical understanding is not purely symbolic but emerges from an active interaction with the environment, rather than just through internal symbolic reasoning (Soylu, 2024). Understanding whether and how numerical magnitude influences children's action judgments would theoretically provide new insights into how abstract representations are linked to action-related systems during development. Practically, it could create educational strategies that better combine motor and numerical learning, especially for children who struggle with mathematics.

The present study aims to investigate whether numerical magnitude influences action-related judgments in children, specifically in the context of graspability assessment. Building on previous findings in adult populations (Badets et al., 2007), the present study investigates whether the effect observed by Badets and colleagues (2007) (a modulation of motor decisions by irrelevant numerical information) can also be seen in school-aged children. In addition, the study investigates whether this effect is modulated by age and numerical competence, both of which are known to influence children's performance on numerical and motor tasks. The aim is to clarify the existence of a number-action interaction in children, and to understand the conditions under which this interaction emerges or fails to emerge.

Based on these premises, the study is guided by the following research questions:

- Does numerical magnitude influence children’s judgments of graspability? In other words, are children more likely to judge an object as graspable when it is preceded by a small number rather than a large one?
- Is the strength of this effect modulated by age? Does the number–action interaction differ between younger and older children in the 6 to 10 years old age range?
- Is the effect modulated by numerical competence, finger gnosia, or fine motor skills?
- Are children with higher numerical skills more (or less) susceptible to this bias?

And the following hypotheses are proposed:

1. H1 – *Main effect of numerical magnitude*. Children will be more likely to judge an object as graspable when it is preceded by a small number (e.g., 1–3) than when preceded by a large number (e.g., 7–9), consistent with the Badets effect.
2. H2 – *Age modulation.* The effect of numerical magnitude on graspability judgments will vary by age. It may be stronger in younger children (6–7 years), who are still developing abstract numerical representations, or stronger in older children (9–10 years), who have more stable numerical-motor integration.

3. H3 – *Numerical competence modulation* Two contrasting patterns are possible: children with higher performance on standardized numerical tests will show a stronger number–action interaction, reflecting more refined internal representations of numerical magnitude. Alternatively, children with lower numerical skills may rely more on embodied strategies, leading to a more pronounced effect.

2. METHOD

2.1 PARTICIPANTS

The final sample consisted of 51 children aged 6 to10 years old recruited from local primary schools in Italy, with a relatively balanced distribution across age groups (Figure 1). All participants were typically developing children with no known neurological, cognitive, or motor impairments. Written informed parental consent was obtained for each child through a signed document prior to data collection, which included explicit consent for the processing of personal data in accordance with EU Regulation 2016/679 (GDPR).

Participants were tested individually in a quiet room during school hours and the sample included both boys and girls from first to fifth grade. Children who were unable to understand the instructions during the practice phase of the experimental task were excluded from the main procedure. The study was approved by the local Research Ethics Committee (protocol number: 1009-a). In addition, explicit parental consent was obtained for the publication of photographs of the experimental materials and children’s hands.

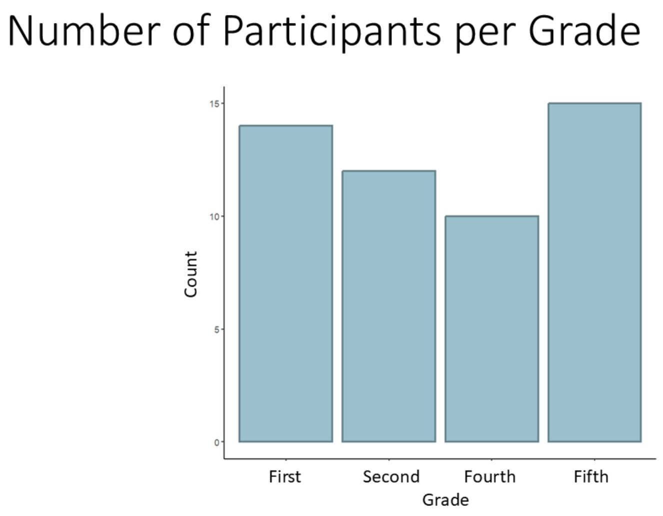
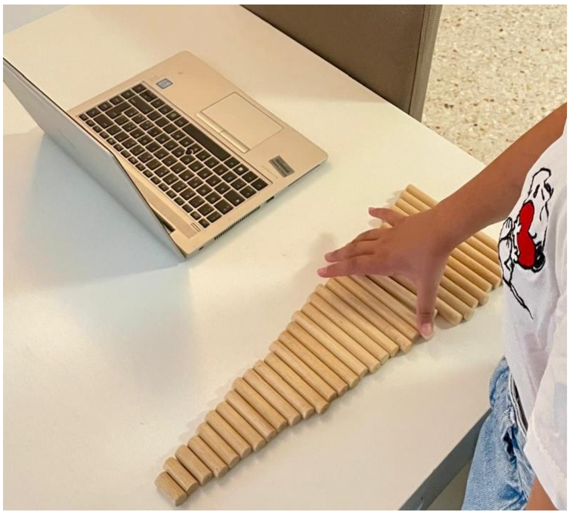


Figure 1. Number of participants per school class.

2.2 MATERIALS AND PROCEDURE

Each child took part in an individual session lasting approximately 30 to 40 minutes. The session consisted of four components: (1) a computerized graspability judgment task adapted from Badets et al. (2007); (2) numerical competence tests from the AC-MT battery (Cesare Cornoldi et al., 2012); (3) a manual dexterity assessment from the ABC battery (Henderson et al., 2007), and (4) a finger gnosis task adapted from Noël (2005) using a tactile response box. The same order was followed for all participants.

At the beginning of the session, the child's maximum grip aperture was measured using real wooden rods 15 mm in diameter and ranging in length from 3.0 to 18.0 cm in 0.5 cm increments. The child tried to grasp progressively longer rods between the thumb and index finger of the dominant hand until failure (Figure 2). The largest successfully grasped rod was recorded as the maximum grip aperture and used to calibrate the computerised graspability task (Figure 3).



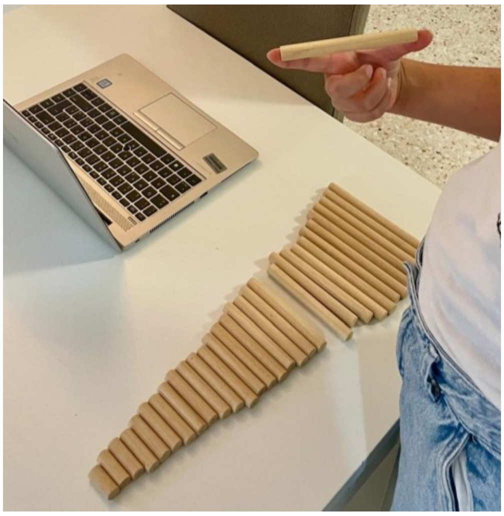


Figure 2. Measuring maximum grip aperture. **Figure 3. Largest rod for calibration.**

In the computerised graspability judgment task, implemented in OpenSesame (v 4.0.24), children sat 40-60 cm from the screen (Figure 4). Instructions were presented both verbally and on-screen, and the experimenter manually entered the child's grasping aperture (in mm) to adjust the stimulus size. Each block began with a fixation, followed by a numerical prime (2, 3, 7 or 8) presented alone and moving on the screen. The prime then appeared on top of each of four sequential rod images, which served as the main stimuli for the graspability judgment. The rods were scaled according to each participant's grasp: ±5%, ±10%, ±15%, ±20% or 0%. Among these, ±5% and ±20% rods were used as control trials, while ±10% and ±15% rods were considered ambiguous, with trials equally distributed between the two conditions. Children verbally indicated whether each rod was graspable. After all eight rods had been presented, children answered to a number comparison task, and specifically whether the numerical prime seen was less than 5 or greater than 5. Responses were recorded via an external keyboard by the experimenter while seated behind the child and out of view. The experimenter pressed '1' for 'yes' (i.e., the rod is graspable) or 'less than 5' (i.e., the number on the rods was less than 5) and '2' for 'no' (i.e., the rod is not graspable) or 'greater than 5' (i.e., the number on the rods was greater than 5). After 4 practice trials, the main task consisted of 8 blocks of 4 graspability trials each (32 in total) plus 8 magnitude comparison questions (an overall total of 40 trials).

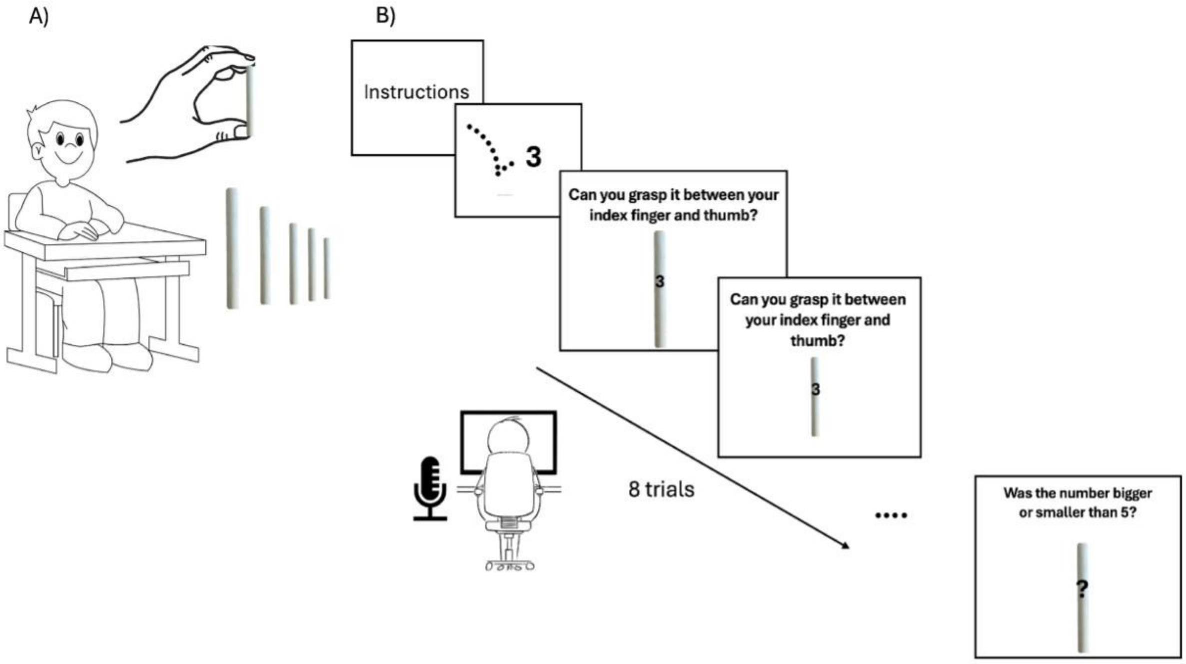


Figure 4. Schematic illustration of the computerized graspability judgment task.

Numerical competence was assessed using the AC-MT battery (REF), with different sets of items for each grade. The first subtest, Numerosity Judgment, had 7 pairs of numbers: children circled the larger number in each pair. The Ordering subtest required the ordering of four numbers in two formats: ascending (5 groups) and descending (5 groups), for a total of 10 sequences. The Written Calculation subtest had 2 arithmetic problems (e.g. 36 + 15 and 28 × 4). The Mental Arithmetic subtest consisted of 6 oral arithmetic problems adapted to the grade level. The Enumeration subtest involved counting backwards aloud from 100 to 50 (from 1 to

20 for 6-year-olds). The Number Dictation subtest consisted of writing down 6 orally dictated numbers. Response times and number of errors were recorded for each subtest.

The ABC battery evaluated manual dexterity using three tasks that differed by age group.

- For 6-year-olds:

In the Coin Insertion task (Figure 5, Figure 6), children inserted 12 coins (round chair felt pads) into a piggy bank one at a time, starting with the dominant hand and then the non-dominant hand. The non-dominant hand was placed on the thigh. Children were explicitly instructed to insert only one coin at a time. The time taken to complete the task with each hand was recorded in seconds.

Figure 5. Coin Insertion task.

Figure 6. Coin Insertion task.

The Bead Threading task involved threading 12 wooden cubes using a plastic needle and string (Figure 7). The child performed the task with their preferred hand (Figure 8). Time and unusual behaviour (e.g. holding the needle with both hands) were recorded. A 0.8 x 15mm wooden stick with a thickness of 15 millimetres was used to construct the cubes.

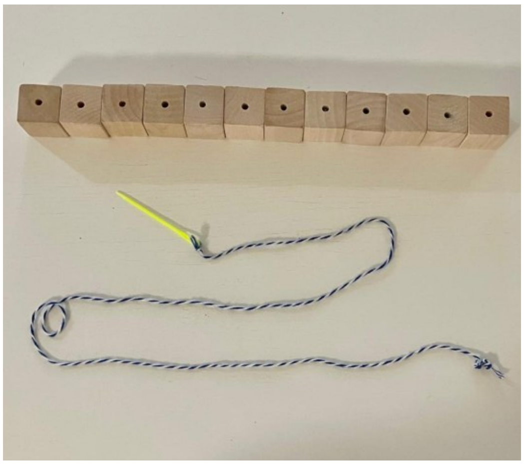


Figure 7. Bead Threading task materials. **Figure 8. Bead Threading task execution.**

The Maze Tracing task (Figure 9) involved tracing a simple maze with a thick marker without lifting the pen or crossing boundaries. One practice trial was allowed; the test could be repeated once if necessary. Time, hand used, and errors were recorded.

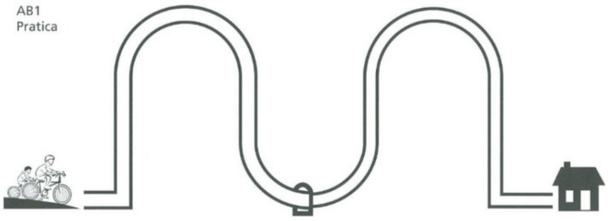


Figure 9. Maze Tracing Task for 6 years old children.

- For children aged 7-10:

In the Pegboard task (Figure 10 and Figure 11), children inserted 12 wooden pegs into a 3×4 board (four rows of three holes with each hole spaced 3.5cm apart), first with the dominant hand, then with the non-dominant hand. The non-dominant hand rested on the thigh. Children were explicitly instructed to insert only one peg at a time. Time per hand was recorded.

Figure 10. The Pegboard Task. **Figure 11. The Pegboard Task.**

In the Lacing task, children passed a lace through 8 equidistant holes (3.5 cm apart) in a wooden board from bottom to top and front to back, following a fixed starting position (Figure 12). Time to completion was recorded.

Figure 12. Lacing Task execution.

The Maze Tracing task (Figure 13) used a more complex maze and a standard ballpoint pen. As above, one practice and up to two test trials were allowed. Time, hand used, and number of errors were recorded.

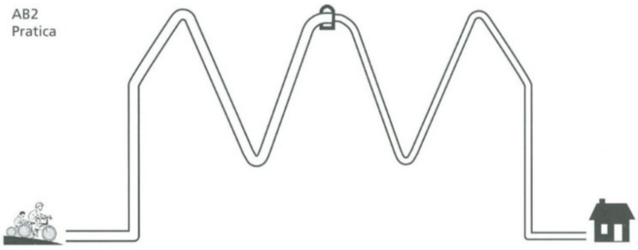


Figure 13. Maze Tracing Task for 7 to 10 years old children.

The Finger Gnosis task assessed tactile digit recognition. The child sat with one hand at a time (always starting with the right hand), palm down, under a wooden box, out of sight. The experimenter, sitting opposite, gently touched one or two fingers at the same time, using a brushing motion towards the fingertip. The child indicated the touched fingers by pointing with the other hand to a printed diagram of a hand placed next to the box, corresponding to the hidden hand (Figure 15). Before putting each hand into the box, the participant was asked to place it on top of the hand drawn on the paper, to make the match obvious (Figure 14). A demonstration trial preceded the test.

Each hand underwent 10 trials, in the following fixed order:

- Right hand: (1) index, (2) thumb + middle, (3) ring, (4) middle, (5) thumb + ring, (6) thumb, (7) index + ring, (8) pinky, (9) index + pinky, (10) middle + pinky
- Left hand: (1) middle, (2) ring, (3) thumb + middle, (4) pinky, (5) thumb, (6) index + ring, (7) middle + pinky, (8) index, (9) index + pinky, (10) thumb + ring

Scoring: 1 = correct, 0.5 = partially correct (one finger was correct and one was not correct), 0 = incorrect.

Figure 14. Hand placement before the box.

Figure 15. Finger Gnosis task.

2.3 ANALYSES

The data were analysed using JASP (JASP Team, 2024), and R (R Core Team, 2024). The primary dependent variable was the percentage of affirmative responses, which reflected the perceived graspability of the rods. Additionally, descriptive statistics were computed for each condition in order to visualise the overall pattern of responses. Bar plots were used to illustrate response tendencies based on numerical magnitude and rod characteristics.

A repeated-measures analysis of variance (ANOVA) was conducted with Numerical Magnitude (small: 2-3 vs. large: 7-8) and Rod Type (more ambiguous: ±15%, ±20% vs. less ambiguous: ±15%, ±20%) as within-subject factors, and School Level (lower grades: first and second vs. upper grades: fourth and fifth) as a between-subject factor. The aim was to assess whether graspability judgments were influenced by the numerical prime, the physical ambiguity of the stimulus, and the child's age.

Finally, to explore if individual differences modulated the magnitude effect, we conducted a set of Pearson correlations in R: for each participant, we computed an individual number effect score, defined as the difference in “yes” responses between small and large numbers in ambiguous trials only. We then correlated this score with measures from three standardised tasks:

- the AC-MT battery (mathematical accuracy and reaction times)
- the Finger Gnosis Test (mean score per participant)
- the ABC battery (mean reaction time across trials)

3. RESULTS

Descriptive statistics showed that children generally performed the graspability judgment task correctly. Accuracy in control trials involving clearly graspable or non-graspable rods was high overall, suggesting that participants understood the task and responded consistently. Moreover, number comparison accuracy was high across school levels (see Figure 16) and children could correctly identify whether the prime number was smaller or larger than five, suggesting that they could perceive and process the numerical stimuli.

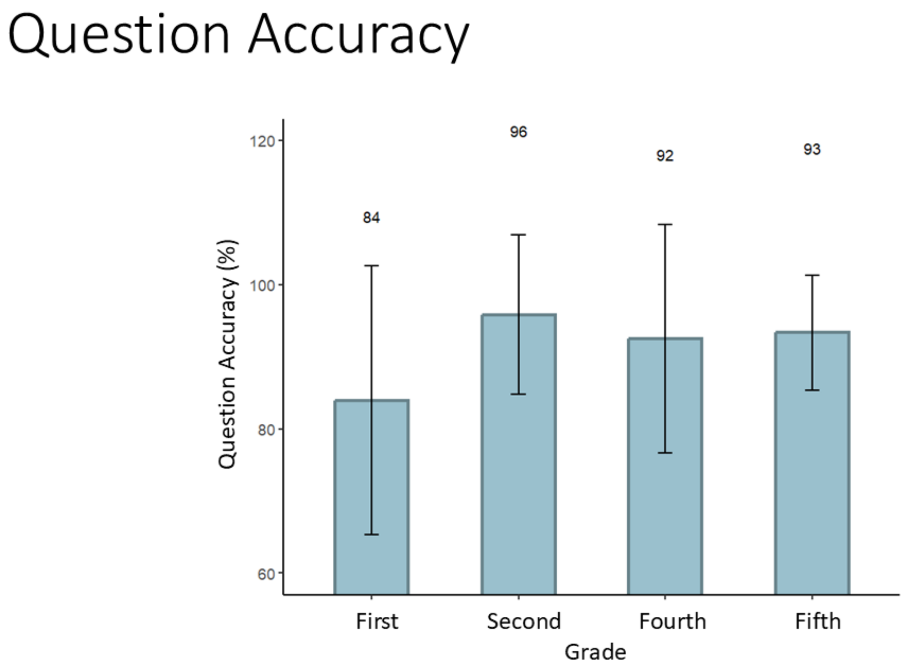
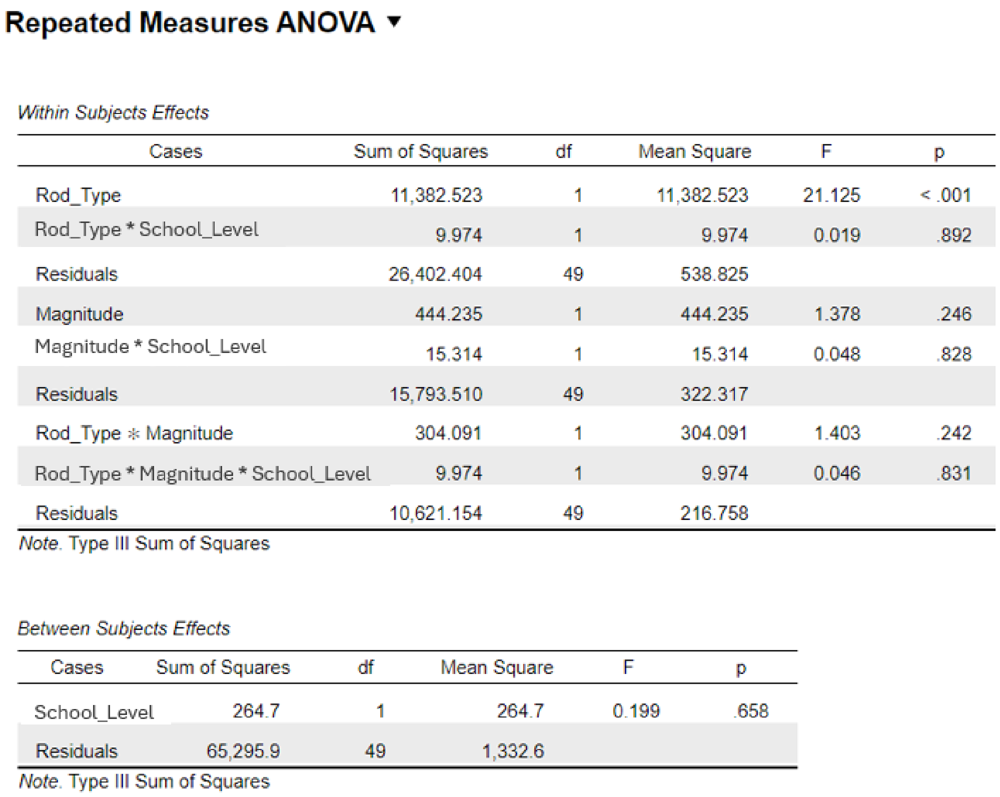


Figure 16. Percentage of correct responses in the number comparison task (“Is the number smaller or greater than five?”) across School Levels.

The repeated-measures ANOVA showed a clear effect of Rod Type: children said “yes” more often for less ambiguous rods than for more ambiguous ones. The results of the repeated-measures ANOVA are reported in Table 1.



Repeated Measures ANOVA ▼

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p
Rod_Type	11,382.523	1	11,382.523	21.125	< .001
Rod_Type * School_Level	9.974	1	9.974	0.019	.892
Residuals	26,402.404	49	538.825		
Magnitude	444.235	1	444.235	1.378	.246
Magnitude * School_Level	15.314	1	15.314	0.048	.828
Residuals	15,793.510	49	322.317		
Rod_Type ✻ Magnitude	304.091	1	304.091	1.403	.242
Rod_Type * Magnitude * School_Level	9.974	1	9.974	0.046	.831
Residuals	10,621.154	49	216.758		

Note. Type III Sum of Squares

Between Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p
School_Level	264.7	1	264.7	0.199	.658
Residuals	65,295.9	49	1,332.6		

Note. Type III Sum of Squares

Table 1. The complete ANOVA results.

Figure 17 shows the direct comparison between less and more ambiguous rods, divided by school level, which corresponds to the main effect reported in the ANOVA. In contrast, there was no effect of Numerical Magnitude and no significant interactions between the factors.

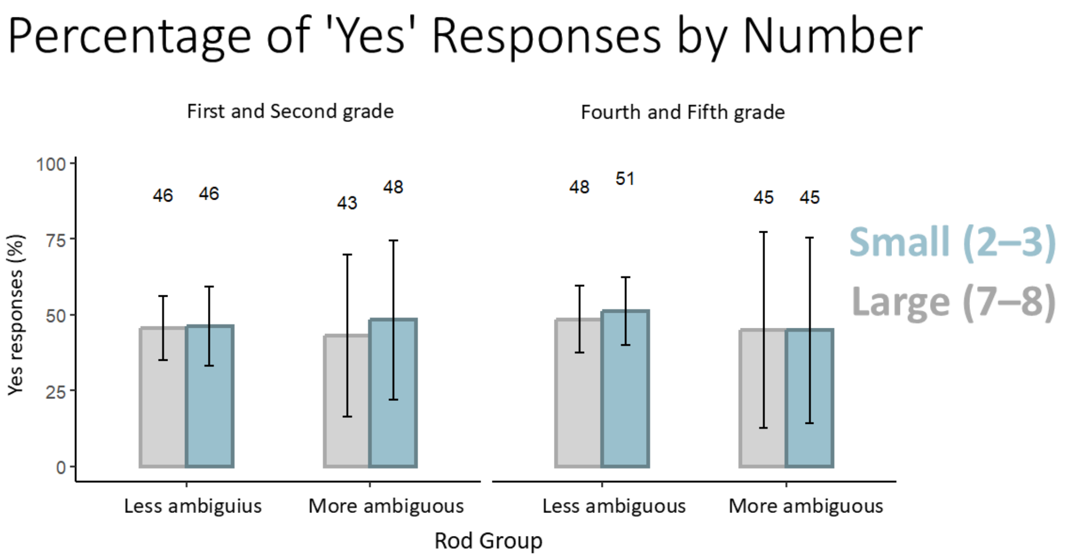


Figure 17. Percentage of "yes" responses for less ambiguous vs. more ambiguous rods, divided by school level.

Figure 18 shows mean graspability accuracy by school level, highlighting the overall performance across age groups.

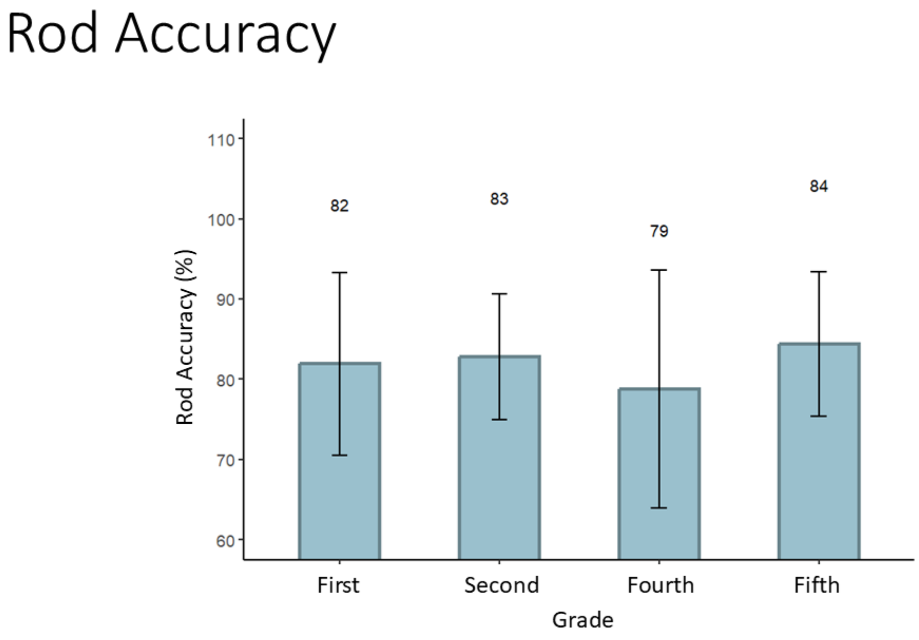


Figure 18. Mean graspability accuracy (%) by school level.

As Figure 19 shows, the graspability accuracy was similar for rods preceded by small and large numbers across all school levels, indicating that numerical magnitude did not affect task performance.

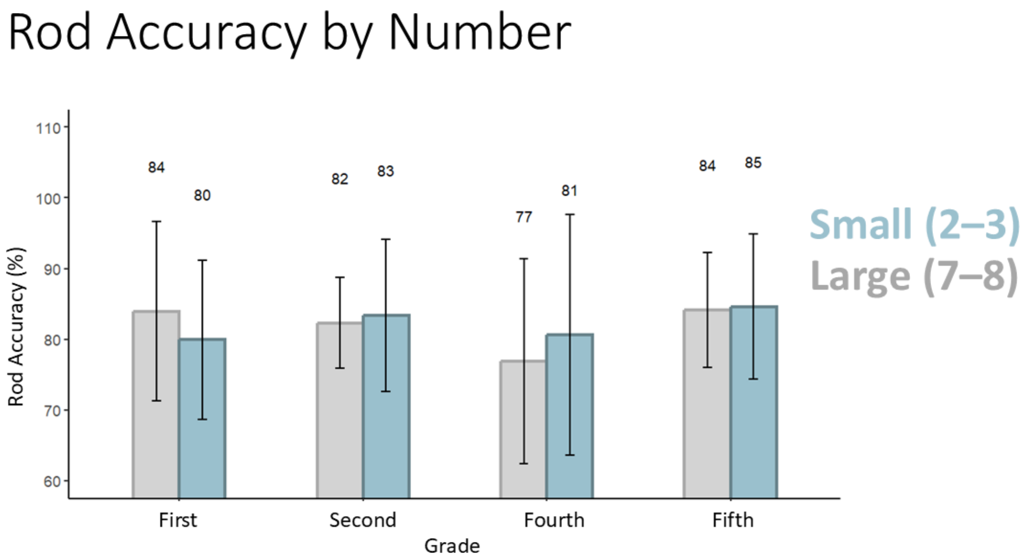


Figure 19. Percentage (%) of correct graspability responses by number (small: 2-3 vs. large: 7-8) and school level.

We also explored how the percentage of “yes” responses varied across rod lengths for each school class. As shown in Figure 20, children judged short rods as graspable more often than long rods. This was confirmed by a significant effect of Rod Type (F(1,49) =21,12, p< .001), while no significant effects of Numerical Magnitude or interactions with school level were found.

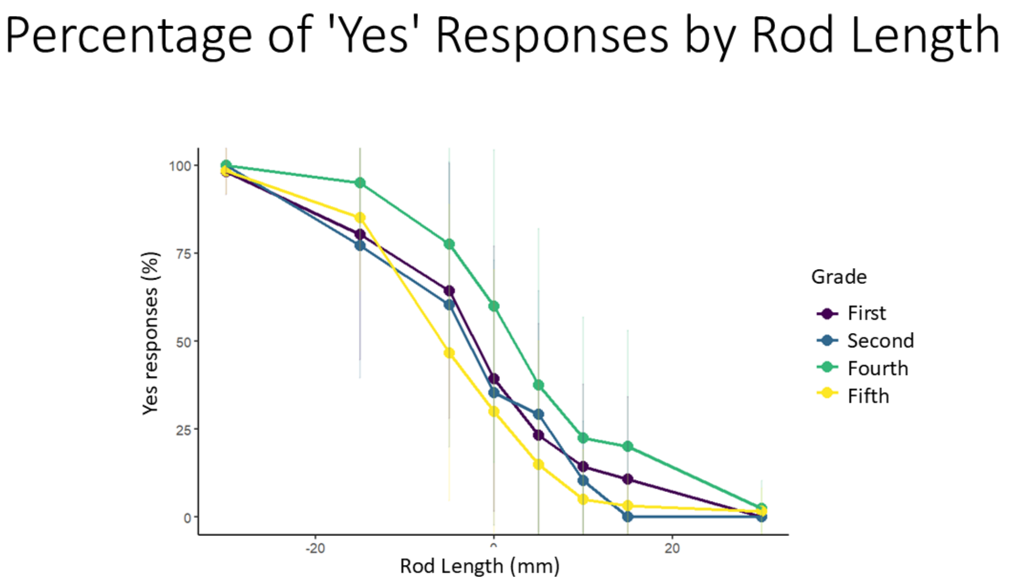


Figure 20. Percentage of "yes" responses varied across rod length and school class.

Overall, the analyses did not reveal evidence of a number-action interaction: children's graspability judgements were influenced by rod characteristics, but not by numerical primes.

In addition, we explored whether variability in the number effect at an individual level was associated with performance in standardised tasks. Specifically, we computed correlations between each child's number effect, defined as the difference in 'yes' responses to small versus large numbers in ambiguous trials (a positive value of this score indicates more "yes" responses after small numbers than after large numbers, consistent with the hypothesised effect, while a negative value means the opposite, with more "yes" responses after large numbers). We then correlated this score with measures from the AC-MT mathematics battery, the finger gnosis test and the ABC motor tasks. The number effect showed a small positive correlation with AC-MT reaction times, indicating that children with slower numerical processing tended to exhibit a greater influence of numbers on their action judgements (see Figure 21), but this correlation did not reach statistical significance. No significant correlation was found with AC-MT accuracy (Figure 22) or finger gnosis (Figure 23). A weak correlation was also observed with ABC reaction times (Figure 24). These results suggest that while the number effect was not robust at the group level, it may still be modulated by individual differences in processing speed.

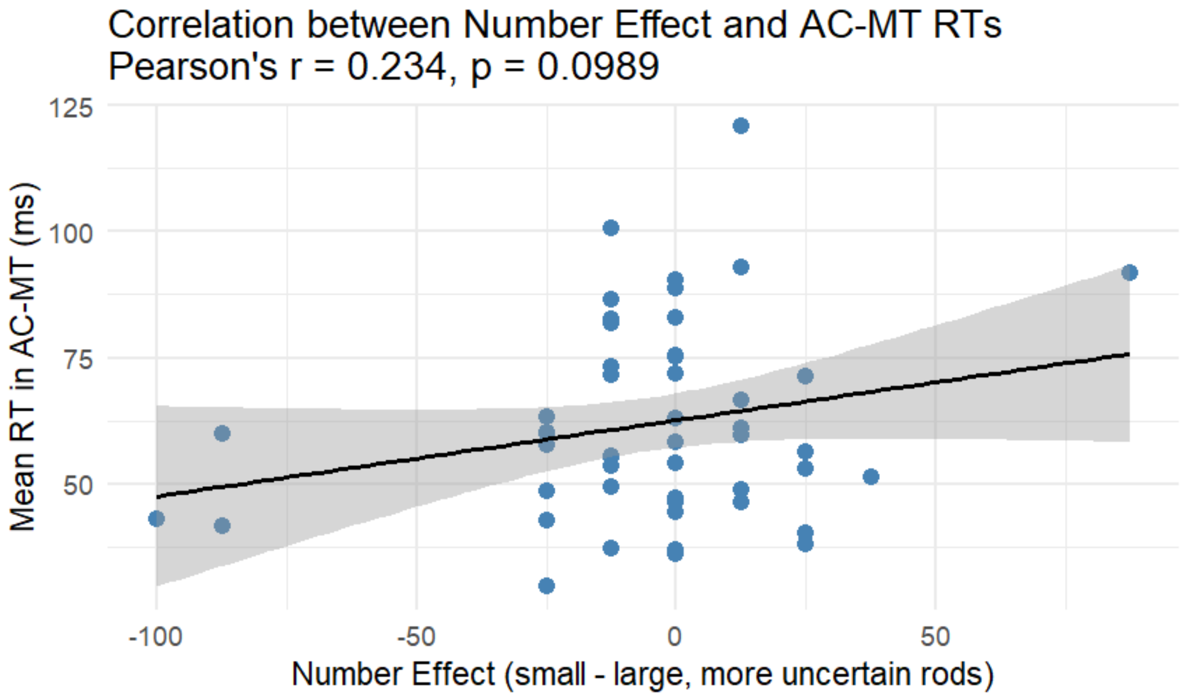


Figure 21. Correlation between Number Effect and AC-MT reaction times

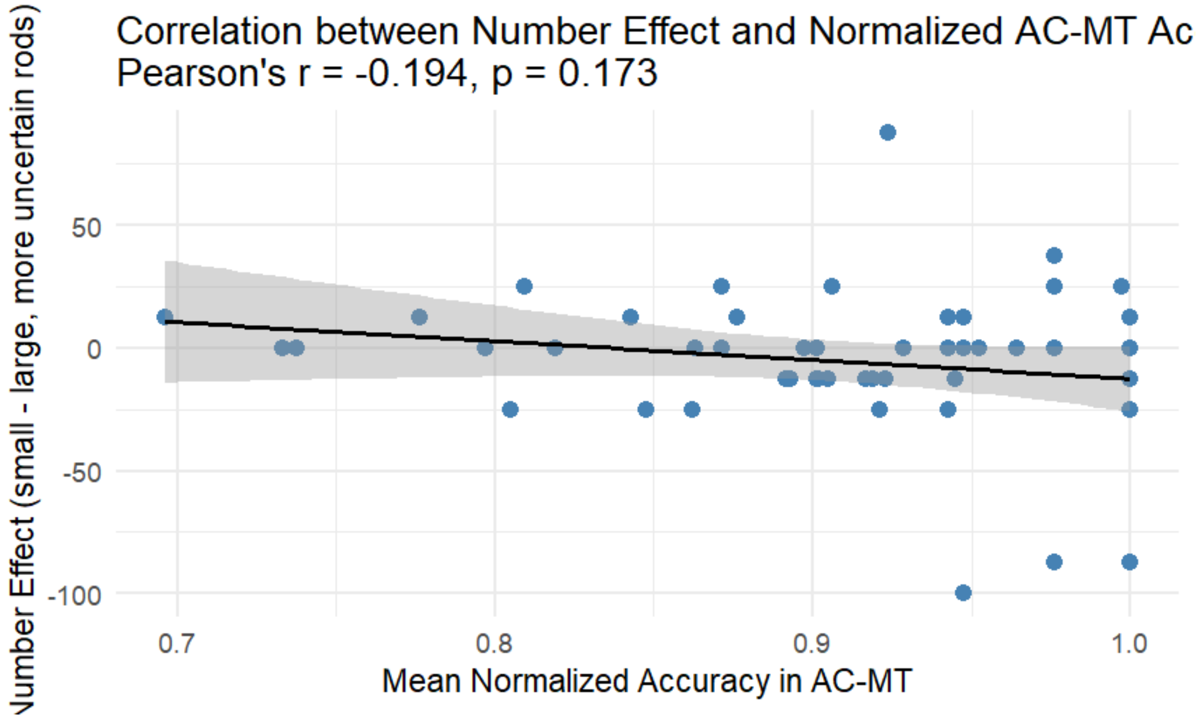


Figure 22. Correlation between Number Effect and normalised AC-MT accuracy

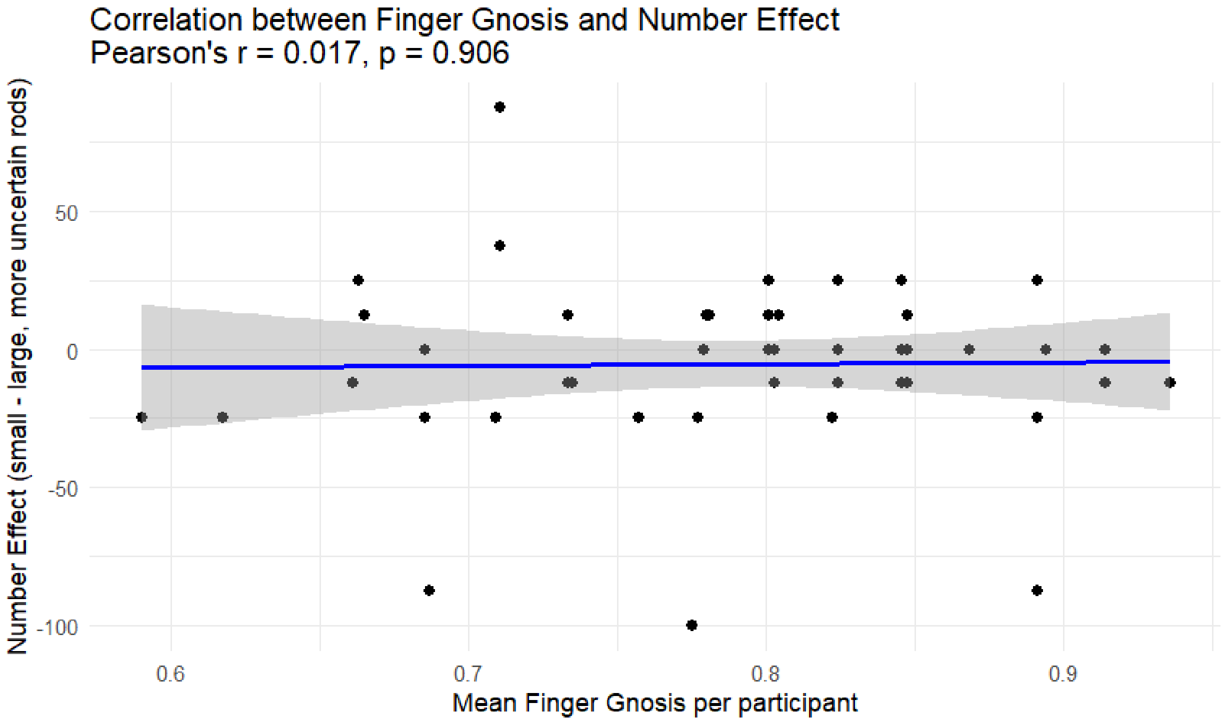


Figure 23. Correlation between Number Effect and Finger Gnosis

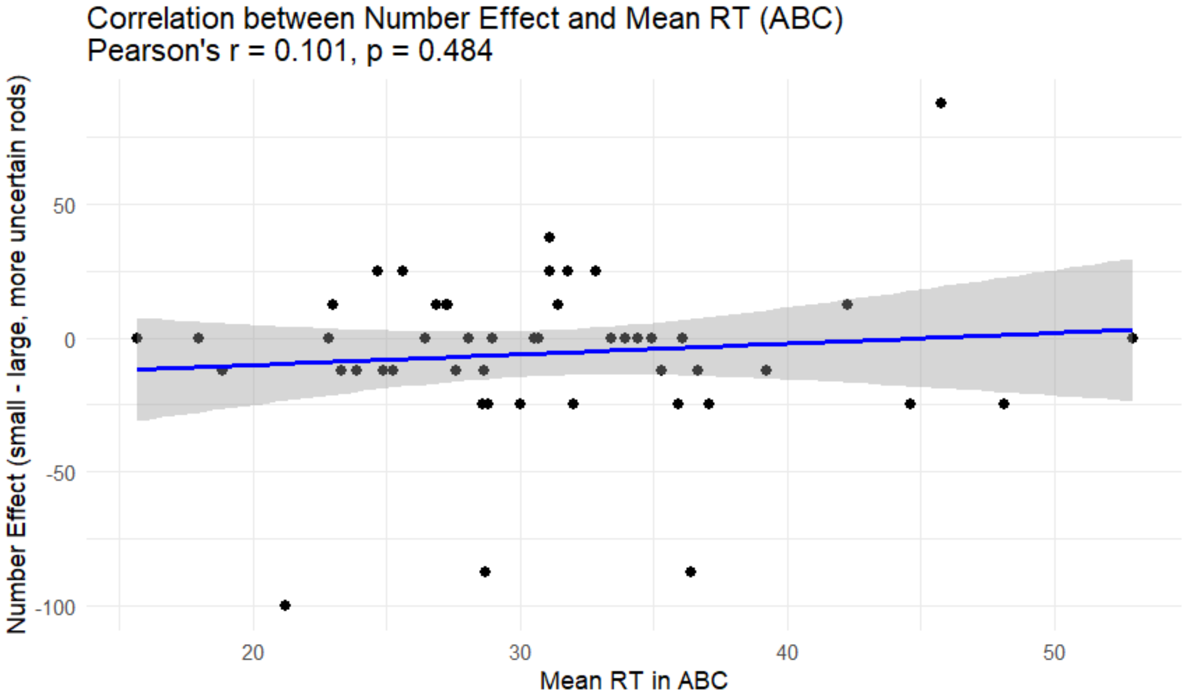


Figure 24. Correlation between Number Effect and ABC reaction times

4. DISCUSSION

This study aimed to investigate whether numerical magnitude influences children's action-related judgements, particularly in the context of a graspability task. While previous research with adults (Badets et al., 2007) showed that small numbers increase the likelihood of objects being judged as graspable, the present findings suggest that this effect does not generalise to school-aged children.

As expected, our results revealed an effect of rod ambiguity: children were more likely to respond "yes" when the rods were clearly within their grasp range. This confirms that the task effectively stimulated sensorimotor judgements and that participants were sensitive to the physical characteristics of the stimuli. Furthermore, the percentage of affirmative responses decreased progressively with increasing rod length, reinforcing the idea that children calibrated their responses based on perceived graspability.

However, contrary to our initial hypothesis (H1), numerical magnitude did not affect graspability judgements. Children gave similar responses regardless of whether the rod was preceded by a small number (2–3) or a large number (7–8). Although no main effect was found, there was a slight descriptive trend suggesting that younger children might be somewhat more influenced by numerical primes in ambiguous trials.

There are several possible explanations. Children may not yet have formed strong enough associations between numerical magnitude and motor representations for the number-action interaction to emerge. While they clearly processed the numerical primes, as demonstrated by their accuracy in the number control task, this information may not have influenced their action judgements. Another possible explanation lies in the limited number of trials and the nature of the statistical approach. Future studies with more trials or alternative analyses may reveal different results.

To explore individual variability (H3), we correlated the number effect with performance in standardised tests. The only notable result was a small positive correlation with reaction times in the AC-MT task, suggesting that children who took longer to process numerical information tended to be more influenced by numbers when making graspability judgements. However, despite this promising trend, this correlation did not reach statistical significance. Future studies with larger samples may be able to determine whether this effect is reliable.

No relevant associations emerged with accuracy, finger gnosis or motor skills. While no general number-action effect was observed, these findings suggest that individual differences in numerical processing speed may influence how symbolic magnitude interacts with action-related decisions.

In any case, our findings support the idea that children's perception of affordances is based on the physical properties of the stimulus rather than abstract symbolic cues, in line with developmental models which suggest that embodied numerical representations evolve gradually, requiring either more experience or a stronger integration of sensorimotor and symbolic systems before such interactions become automatic.

In conclusion, this study did not confirm the number–action interaction predicted by our initial hypotheses, but it did reveal that children mainly based their graspability judgements on rod ambiguity. These results refine, rather than contradict, the embodied perspective: they indicate that numerical effects on action judgements may emerge only under specific developmental conditions, such as when number concepts are deeply internalised, or when tasks place a greater demand on motor planning systems. The current findings provide a developmental boundary for the Badets effect and emphasise the significance of age and task characteristics in shaping embodied interactions.

5. CONCLUSION

This study examined whether numerical magnitude influences children's judgements of graspability, in order to contribute to the growing body of literature on embodied numerical cognition. Although the children were clearly sensitive to the physical features of the stimuli, adjusting their responses based on rod ambiguity and length, no effect of numerical primes was found. These findings suggest that symbolic numbers may not yet be strongly linked to motor representations involved in action-related decisions in this developmental phase. Rather than contradicting the embodied perspective, the absence of a number-action effect emphasises the specificity of this effect to development and the role of task conditions in shaping these interactions. By clarifying the circumstances in which embodied effects emerge, this study provides a valuable foundation for future research on the interplay between numerical and motor systems during development.

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